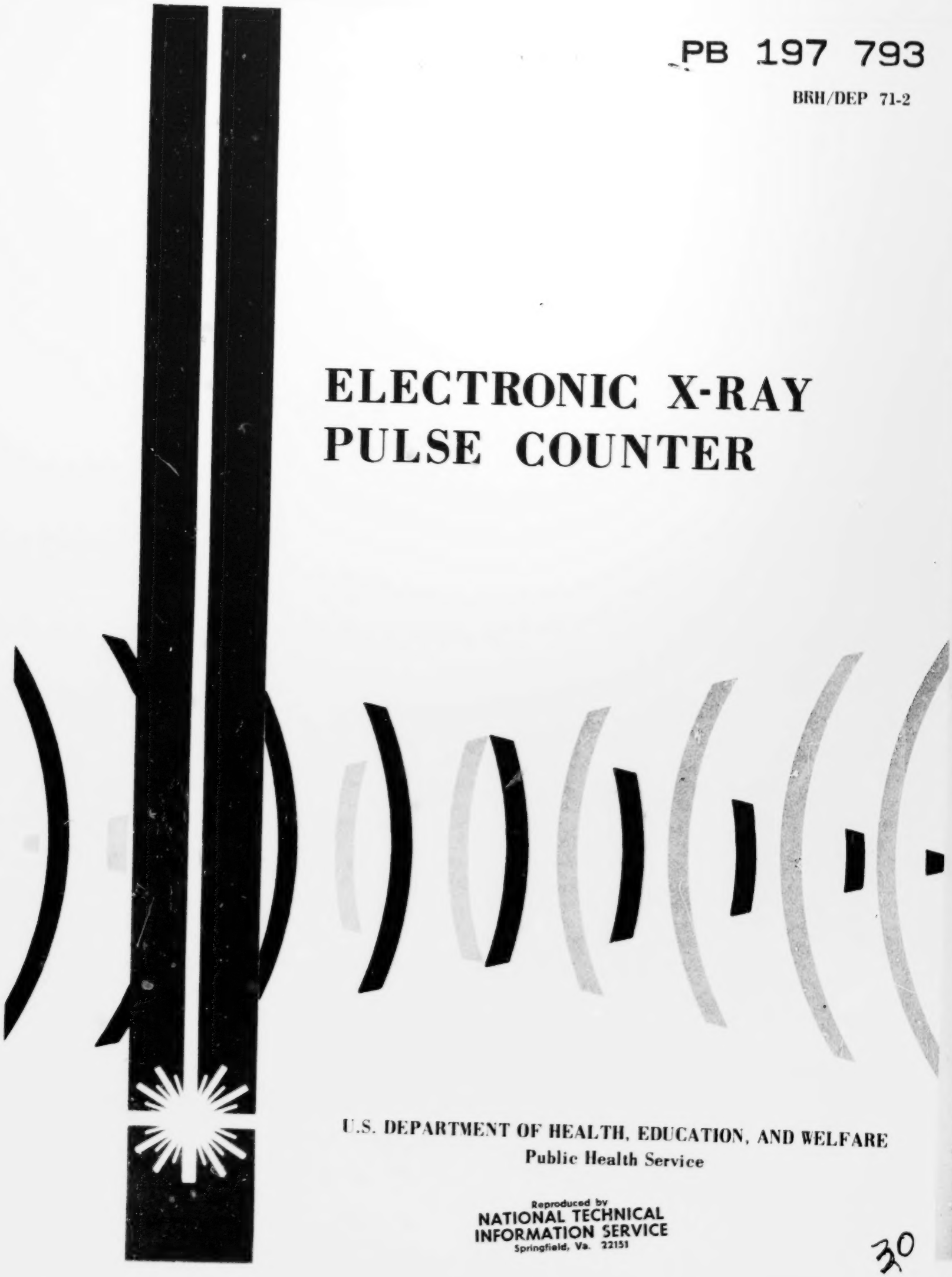
PB 197 793

BRH/DEP 71-2

ELECTRONIC X-RAY PULSE COUNTER



U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

30

DIVISION OF ELECTRONIC PRODUCTS

Technical Reports

Technical reports of the Division of Electronic Products, Bureau of Radiological Health, are available from the National Technical Information Service (NTIS), Springfield, Va. 22151. The PB number (which should be cited when ordering) and the price for paper copy are indicated after the title. Price for microfiche copy is $0.95. Bulk order prices may be obtained from NTIS.

	Title
TSB-1	Instrument for Measurement of X-ray Emission from Television Sets (January 1968) (PB 178 808 $6.00)
TSB-2	A Pilot Survey of X-radiation Emissions from Color Television Receivers (In Pinellas County, Florida)(June 1968) (PB 178 809 $6.00)
TSB-3	A Survey of X-radiation from Color Television Sets in the Washington, D.C., Metropolitan Area (March 1968) (PB 178 810 $6.00)
TSB-68-4	Biological Aspects of Microwave Radiation - A Review of Hazards (July 1968) (Reprinted August 1969) (PB 185 964 $6.00)
TSB-5	Report of Preliminary Measurements of Electromagnetic Radiation Fields Near Microwave Ovens (December 1968) (PB 185 967 $6.00)
DEP-69-1	X-radiation Control Programs in the Color Television Industry - Summary Report on Visits to Manufacturers - May 1968-December 1968 (March 1969) (PB 185 979 $3.00)
DEP-69-2	A Field Method for the Determination of Lead in Glass Used for Shielding Television Receiver Components (December 1969) (PB 189 703 $3.00)
BRH/DEP 70-1	X-ray Emission from Cold-Cathode Gas Discharge Tubes Used for Educational Purposes (February 1970) (PB 189 890 $3.00)
BRH/DEP 70-2	Report of Tests Made on the Westinghouse Panoramix® X-ray Machine (March 1970) (PB 190 399 $3.00)
BRH/DEP 70-3	Description and Evaluation of a Fluoroscopic Screen Visual Brightness Comparer (March 1970) (PB 190 870 $3.00)
BRH/DEP 70-4	Evaluation of a Norelco-Pitchford Portaspec® Portable X-ray Spectograph (March 1970) (PB 190 876 $3.00)
BRH/DEP 70-5	A Study of Head and Neck Exposures from Panoramix® Roentgenography (March 1970) (PB 190 964 $3.00)
BRH/DEP 70-6	Laboratory Testing and Evaluation of Color Television Receivers Acquired During the In-Plant Survey (March 1970) (PB 191 090 $3.00)
BRH/DEP 70-7	A Comparison of Microwave Detection Instruments (April 1970) (PB 191 395 $3.00)
BRH/DEP 70-8	Development of Liquid Crystal Microwave Power Density Meter (May 1970) (PB 191 396 $3.00)
BRH/DEP 70-9	Product Testing and Evaluation of Giant View® TV Projector (May 1970) (PB 191 906 $3.00)
BRH/DEP 70-10	Survey of Selected Industrial Applications of Microwave Energy (May 1970) (PB 191 394 $3.00)
BRH/DEP 70-11	Leakage Variations from Microwave Ovens (June 1970) (PB 192 042 $3.00)
BRH/DEP 70-12	The Effect of Instrument Averaging Time on Microwave Power Density Measurements (June 1970) (PB 192 322 $3.00)
BRH/DEP 70-13	Variability in the Automatic Processing of Medical X-ray Film (June 1970) (PB 192 702 $3.00)
BRH/DEP 70-14	Simple X-ray Detection Instruments for Television Service Technicians (June 1970) (PB 192 377 $3.00)

(continued on inside of back cover)

BIBLIOGRAPHIC DATA SHEET	1. Report No. BRH/DEP 71-2	2.	3. Recipient's Accession No.
4. Title and Subtitle ELECTRONIC X-RAY PULSE COUNTER			5. Report Date January 1971 6.
7. Author(s) R. Walchle and G. F. Grove, Jr.			8. Performing Organization Rept. No. BRH/DEP 71-2
9. Performing Organization Name and Address X-ray Exposure Control Laboratory Division of Electronic Products 12720 Twinbrook Parkway, Rockville, Md.20852			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE BUREAU OF RADIOLOGICAL HEALTH Rockville, Maryland 20852			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

This paper describes an inexpensive easy-to-build x-ray pulse counter for measuring exposure times of pulsed x-ray machines. Knowledge of the rectification type in the machine and the line frequency allows conversion from number of pulses to exposure time. The instrument will count at rates as low as 2.2 mR per pulse and displays the result on a digital readout.

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
RELEASE UNLIMITED	UNCLASSIFIED	30
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.00

BRH/DEP 71-2

ELECTRONIC X-RAY PULSE COUNTER

R. Walchle and G.F. Grove, Jr.

X-ray Exposure Control Laboratory
Division of Electronic Products

January 1971

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Radiological Health
Rockville, Maryland 20852

The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health, Education, and Welfare, Public Health Service.

FOREWORD

The Bureau of Radiological Health continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in Radiological Health Data and Reports (a monthly publication), Public Health Service numbered reports, appropriate scientific journals, and technical report series for the Bureau's divisions, offices, and laboratories.

The technical reports of the Division of Electronic Products (DEP) allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the National Technical Information Service.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

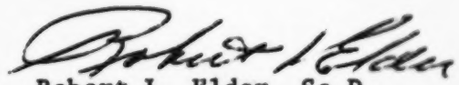
John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The development of instrumentation for measuring radiation exposure from electronic products is a major responsibility of the Division of Electronic Products, Bureau of Radiological Health. It is the responsibility of the Division's X-ray Exposure Control Laboratory to develop instruments for testing the performance of x-ray equipment. This report describes the results of our effort to design a simple and inexpensive instrument that could be used to measure the accuracy of x-ray exposure timers.

The device described in this report was designed to be constructed by electronic technicians without specialized radiation measurement instrumentation experience. It can be built from commonly available, low-cost components, and calibration is unnecessary because the line frequency is used as a time standard.

Construction and use of the instrument described herein will allow groups which have limited budgets to accurately measure x-ray exposure time.



Robert L. Elder, Sc.D.
Acting Director
Division of Electronic Products

CONTENTS

	Page
FOREWORD	iii
PREFACE	v
FIGURES	viii
ABSTRACT	ix
1. INTRODUCTION	1
2. GENERAL DESCRIPTION	2
3. PERFORMANCE CHARACTERISTICS	4
4. LIMITS OF APPLICABILITY	6
5. CONCLUSIONS	6
REFERENCES	7
APPENDIX A - COMPONENT LIST	15

FIGURES

		Page
Figure 1.	Exterior view of electronic x-ray pulse counter . .	9
Figure 2.	Block diagram of electronic x-ray pulse counter . .	10
Figure 3.	Schematic diagram of electronic x-ray pulse counter	11
Figure 4.	Interior view of electronic x-ray pulse counter . .	12
Figure 5.	Printed circuit board top view with component outlines	13
Figure 6.	Printed circuit board pattern - bottom view	14

ABSTRACT

This paper describes an inexpensive, easy-to-build x-ray pulse counter for measuring exposure times of pulsed x-ray machines. Knowledge of the rectification type in the machine and the line frequency allows conversion from number of pulses to exposure time. The instrument will count at rates as low as 2.2 mR per pulse and displays the result on a digital readout.

BLANK PAGE

ELECTRONIC X-RAY PULSE COUNTER

1. INTRODUCTION

There are several methods for determining exposure times in pulsating x-ray generators. The method most commonly used is the spinning top. In this procedure, which has been described by Ter Pogossian (1), film is used as the sensing medium. Another less common method employs a solenoid-activated impulse recorder. The device is electrically connected across the primary winding of the high-voltage transformer of an x-ray machine and is moved across a paper during an exposure. A small mark is recorded for each voltage surge (two per complete cycle) on the 60-Hz supply (2).

Advantages of the spinning top and impulse-recorder devices are excellent portability, low initial cost (less than $20.00), and excellent accuracy. These devices, however, have several disadvantages. The spinning top method requires the exposure of radiographic film for each measurement, and the results are immediately available only if Polaroid film is used. A disadvantage of the impulse recorder is that it requires electrical connection to the primary winding of the high-voltage transformer.

Another device for measuring the length of an exposure has been used by Higgins, Rosenbaum, and DeVore (3). This device involves the use of an x-ray detector, an electronic pulse counting circuit, and decimal readout tubes. X-ray pulses strike a semiconductor detector, and current pulses are generated in it. These pulses are amplified and shaped so that they may be electronically counted, and the total number of pulses is registered on a series of decimal readout tubes.

The advantages of the Higgins device are that there are no electrical connections to the x-ray machine, results are instantaneous, and there are no continuing operational costs as with the spinning top. Disadvantages of the Higgins device are that it is less portable than the other devices and the initial cost is greater.

Keeping in mind the advantages and disadvantages of the methods outlined above, an electronic x-ray pulse counter was designed to provide the following capabilities: (1) high portability in a self-contained unit for use as a survey instrument (2) minimum operating cost by eliminating the use of film, (3) instantaneous readout of results and immediate repeat capability, and (4) elimination of any electrical connection to the x-ray machine. It was felt that such a counter would be useful on a large majority of dental and medical radiographic units, even if it could not be used on constant-potential or three-phase units. If all new parts are used to construct this device, the total cost will be about $160.00.

2. GENERAL DESCRIPTION

The electronic x-ray pulse counter consists of a semiconductor x-ray detector, amplifier, wave-shaper, binary-coded decimal (BCD) pulse counters, digital decoder-drivers, and neon readout tubes. These components are packaged in the aluminum minibox pictured in figure 1. The x-ray detector is an inexpensive silicon diode mounted under a screen window in the top of the box.

The device counts x-ray pulses from pulsed x-ray machines and instantaneously displays the total on the readout tubes. Dividing this number by the pulse rate, 60 Hz for half-wave machines or 120 Hz for full-wave, gives the time in seconds. The counter can be reset to zero with a reset button and a new measurement taken immediately.

The block diagram in figure 2 illustrates in more detail how the x-ray pulse counter works. X-ray pulses strike the detector during an exposure, each pulse generating a current pulse in the detector. These pulses are amplified by an a.c. amplifier and sent to a waveshaping circuit. This circuit, commonly known as a Schmitt trigger, transforms pulses of any shape into rectangular pulses. The rectangular pulses are then sent to the "ones" BCD counter. This counter advances one count with each pulse and its tally is sent to a decoder-driver. The decoder-driver translates the BCD output of the counter to the decimal system and registers the result on a neon readout tubes.

When the "ones" counter has received ten pulses, it returns to zero and sends a carry pulse to the "tens" BCD counter. This process is repeated for the "tens" and "hundreds" counters. After the total number of pulses registered by all three readout tubes reaches 999, the tally returns to 000. Thus, the counter is capable of measuring a real time x-ray exposure of 16.666 seconds pulsed at 60 Hz or 8.333 seconds pulsed at 120 Hz without recycling.

The schematic diagram in figure 3 illustrates the circuit connections of all electrical components used in the x-ray pulse counter, and a description of these parts is presented in the component list in appendix A. The total winding configuration of the power transformer has not been completely represented in the schematic diagram because only one-half of the 125-0-125 volt winding is used in the power supply for the anodes of the readout tubes. The center tap lead and one side is used, while the reamining lead is not connected.

The reader will notice that terminal numbers are not assigned to the readout tube sockets or to the integrated circuit (IC) sockets. Such numbers are not necessary if the following are observed:

(1) The readout tubes should be placed into their sockets so the lighted numerals may be read from the front of the board.

(2) The IC sockets do not have a positional marking, but the integrated circuit counters and decoder-drivers themselves have a small crescent-shaped groove in one end. It may be seen in figure 4 that all the ICs are placed into their sockets with this groove facing away from the readout tubes. The IC voltage regulator has a metal tab which also points away from the readout tubes. One of the two central pins on the readout tube sockets must be flattened against the socket to fit the indicated holes on the circuit board.

Figures 4 and 5 illustrate how components were attached to the printed circuit board. Figure 4 also shows how components not on the printed circuit board were mounted on the aluminum chassis. These include the power transformer (PT), the power transistor (Q8), the fuse post (F), the on-off switch (S_1), and the reset (S_2). The power transformer is normally mounted above the fuse post with the machine screws shown, but it is laid aside in figure 4 to permit a better view of the components on the printed circuit board.

The x-ray detector diode (D6) should be mounted with its axis parallel to the surface of the circuit board, as it is markedly more sensitive to x rays impinging perpendicular to its axis. If the International Rectifier type 5A4 is not available, a Motorola IN4004 may be used. However, other apparently similar diodes may not work as the detector.

Figure 6 is a full size print from the photographic negative used to produce the photo-etched printed circuit board. The reader may photocopy this figure on a 1 to 1 scale to obtain a negative for producing his own printed circuit board. A procedure recommended by Kepro, Inc., was used to produce the printed circuit board. This is a bottom view of the conductor configuration; therefore, the negative obtained by photographing figure 6 must be contact printed with its emulsion facing the circuit board to obtain the desired configuration of copper conductors on a builder's own printed circuit board.

Figure 5 is a top view of the printed circuit board. This view depicts the spatial arrangement of the electrical components superimposed on the interconnections formed by the copper conductors on the board. The intention of this view is to relate the schematic diagram in figure 3 to the pictorial view in figure 4 and to the image of the copper conductors of the printed circuit board in figure 6. The reader will note that the solid black dots in figure 5, which represent component connections to the circuit board, appear as holes in the copper conductors in figure 6. The black dots marked with lower case letters on both figure 3 and figure 5 indicate connections to components not on the printed circuit board. Point "j" is used to connect the circuit board to the chassis at the transformer mounting bolt. The straight solid lines between dots in figure 5 indicate conductor (shorting) bridges placed on the top side of the board to connect copper conductors on the under side of the board. Care should be taken in soldering the germanium diode D7 to avoid overheating it.

All of the components used to construct the device were obtained from commercial vendors. The tools required to work the aluminum minibox were not highly specialized (i.e., electric drill, hand file, hand nibbling tool, etc.)

3. PERFORMANCE CHARACTERISTICS

The electronic x-ray pulse counter was tested in a number of different situations to determine its operating characteristics and limitations. These included tests for dependency on line voltage fluctuations and variations in x-ray beam intensity and energy.

To verify the accuracy of the pulse counter, a fluorescent screen-phototube detector connected to a cathode ray oscilloscope (CRT) with persistence display capability was used in conjunction with the counter. The CRT and phototube combination provided an accurate determination of the number of radiation pulses emitted and an indication of their relative intensities.

A "Variac" auto transformer was used to vary the line voltage to the pulse counter, and the CRT-phototube combination was to check its counting accuracy. Line voltage was varied from 130 to 92 V a.c., and the counter functioned without error. However, below 92 V a.c. the readout tubes failed to glow continuously.

The pulse counter was then checked for accuracy with variations in x-ray tube kilovoltage, current, source-detector distance, and beam intensity. The x-ray machines used were a G.E. dental-100 unit with 3.75 mm Al equivalent filtration and a Westinghouse medical diagnostic unit with approximately 4.0 mm Al equivalent filtration.

On each of the two machines tested, beam intensity was measured with a Victoreen 666 survey meter. A 1-1/4-inch probe attached to the meter was used as the detector. For the tests on the dental machine and the medical diagnostic machine, the survey meter was used in the integrating mode with exposures usually of six-pulse duration.

Tests of the device on both x-ray machines revealed the following:

(1) The device has a minimum beam intensity threshold below which it will not operate properly. This value is approximately 8 R/min for half-wave machines or 16 R/min for full-wave machines. This is 2.2 mR/pulse.

(2) The device will perform accurately with beam intensities up to 5,900 R/min.

(3) The angle of x-ray incidence on the diode detector can be as great as 30 degrees from the vertical and the device will still operate.

(4) The minimum beam intensity threshold was overcome with the dental x-ray machine at 50 kVp, 15 mA, and distances of 14 inches or less from the tube focal spot. The same threshold was likewise overcome with the medical x-ray machine at 80 kVp, 75 mA, and distances of 24 inches or less from the tube focal spot.

Since the amplifier is a.c. coupled, it may respond to the beginning of a series of pulses whose amplitude would be too small to continue to activate it. When setting the counter up for a measurement, the beam intensity should be sufficient to cause counting throughout an exposure of one second. The above sensitivity measurements are based on this requirement.

The sensitivity of the counter can be adjusted by changing R31. The sensitivity is increased by decreasing the value of R31, but excessive sensitivity will cause spontaneous counting, especially at low temperature or line voltage. Because of the temperature limits on the integrated circuits, the counter may not operate properly below $0^{\circ}C$.

4. LIMITS OF APPLICABILITY

As stated previously, the device was designed to count radiation pulses from pulsating x-ray sources. The current pulses generated in the semiconductor detector are amplified with an a.c. amplifier. X-ray beams produced by a constant potential x-ray machine would generate a corresponding constant current in the detector. The a.c. amplifier would transmit only one pulse when the machine was first activated, but no more. The same would probably be true of a three-phase x-ray machine in which the amount of ripple in the anode voltage would be less than 20 percent of the maximum kilovoltage peak without any capacitive effects from the high-voltage cables. The same limitation would occur with pulsed x-ray machines having long high-voltage cables and operating at tube currents (approximately 15 mA or less) insufficient to discharge the cables after each pulse.

5. CONCLUSIONS

The electronic x-ray pulse counter is capable of providing an accurate measurement of the length of an x-ray exposure for single-phase, self-rectified, or full-wave-rectified radiographic machines. It will not operate successfully on three-phase or constant-potential machines.

The pulse counter will operate successfully with a power line voltage as low as 92 volts a.c. It requires an x-ray beam intensity of at least 2.2 mR/pulse, and no degradation of performance was observed at exposure rates up to 5,900 R/min. The angle of x-ray incidence on the detector may be as great as 30 degrees from the vertical.

REFERENCES

(1). TER-POGOSSIAN, MICHEL M. The Physical Aspects of Diagnostic Radiology, page 147, Harper and Row (1967).

(2). THE CXC IMPULSE RECORDER, Form No. 6161R5, Continental X-ray Corp., Chicago, Illinois.

(3). HIGGINS, E. M., H. D. ROSENBAUM, and W. D. DEVORE. Radiation beam analyzer for diagnostic radiology. Amer. Roentgen. 101: 983-987 (1967).

(4). FAIRCHILD SEMI-CONDUCTOR DATA CATALOGUE 1969, Fairchild Semi-Conductor Division, Fairchild Camera and Instrument Corp. (1969).

BLANK PAGE

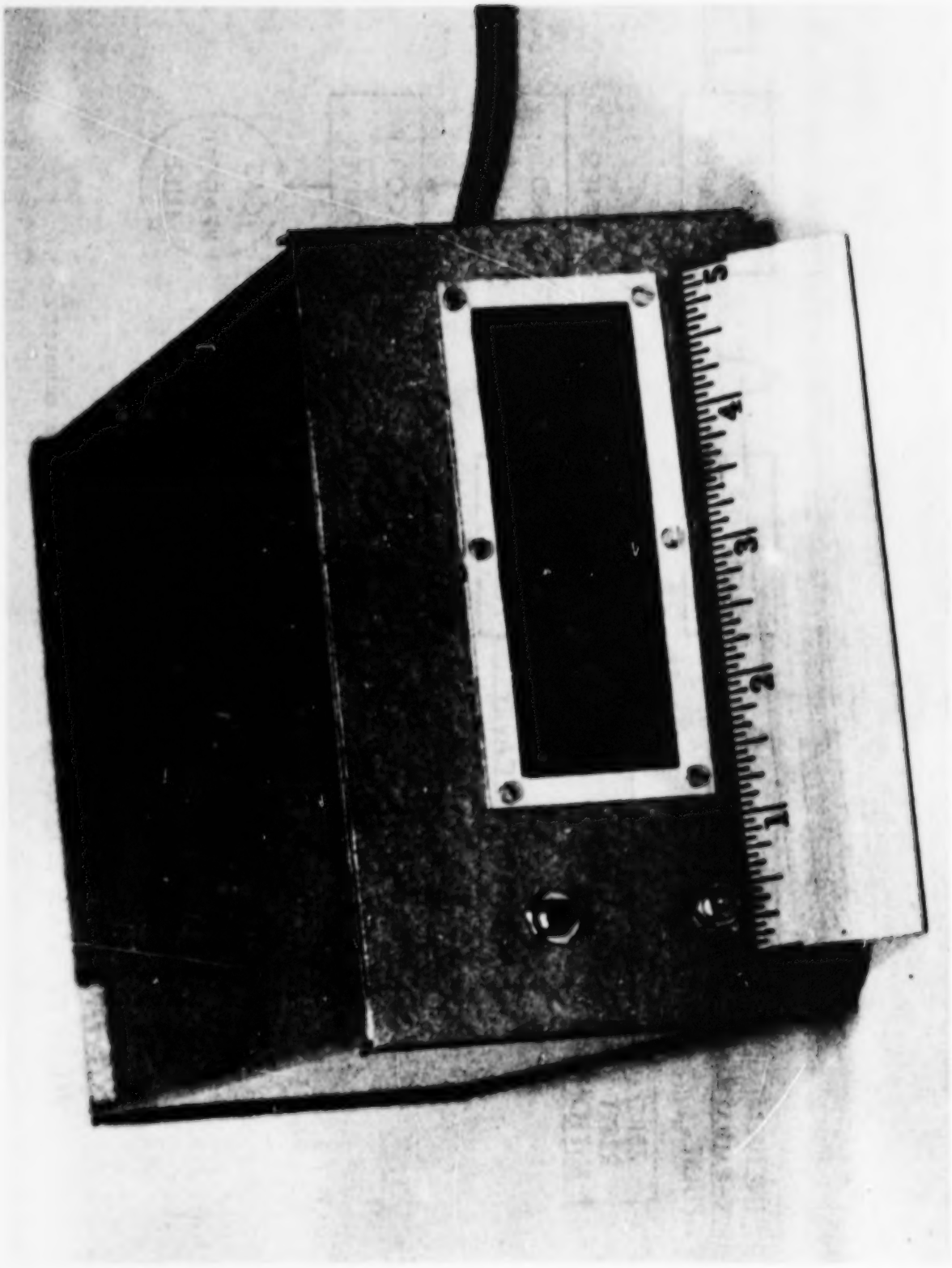


Figure 1. Exterior view of electronic x-ray pulse counter.

Preceding page blank

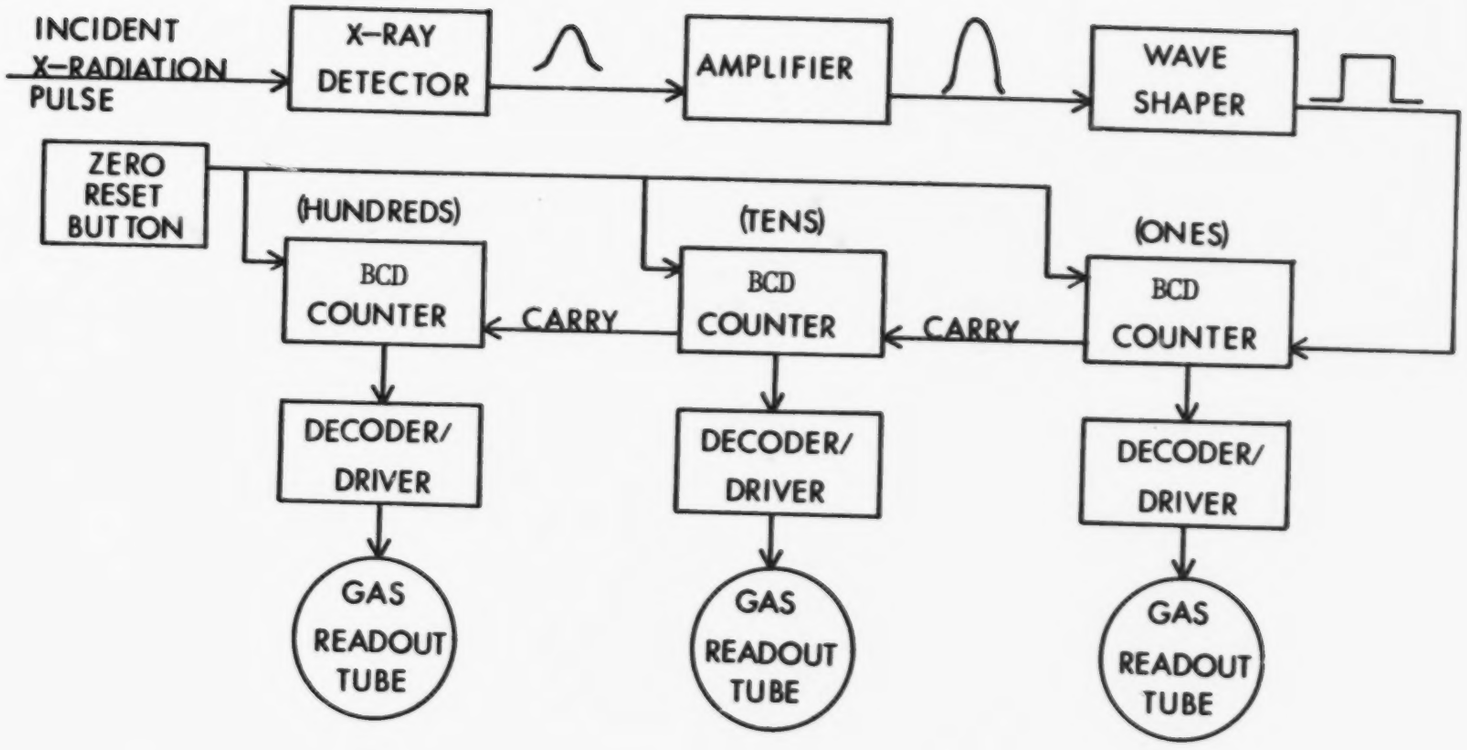


Figure 2. Block diagram of electronic x-ray pulse counter.

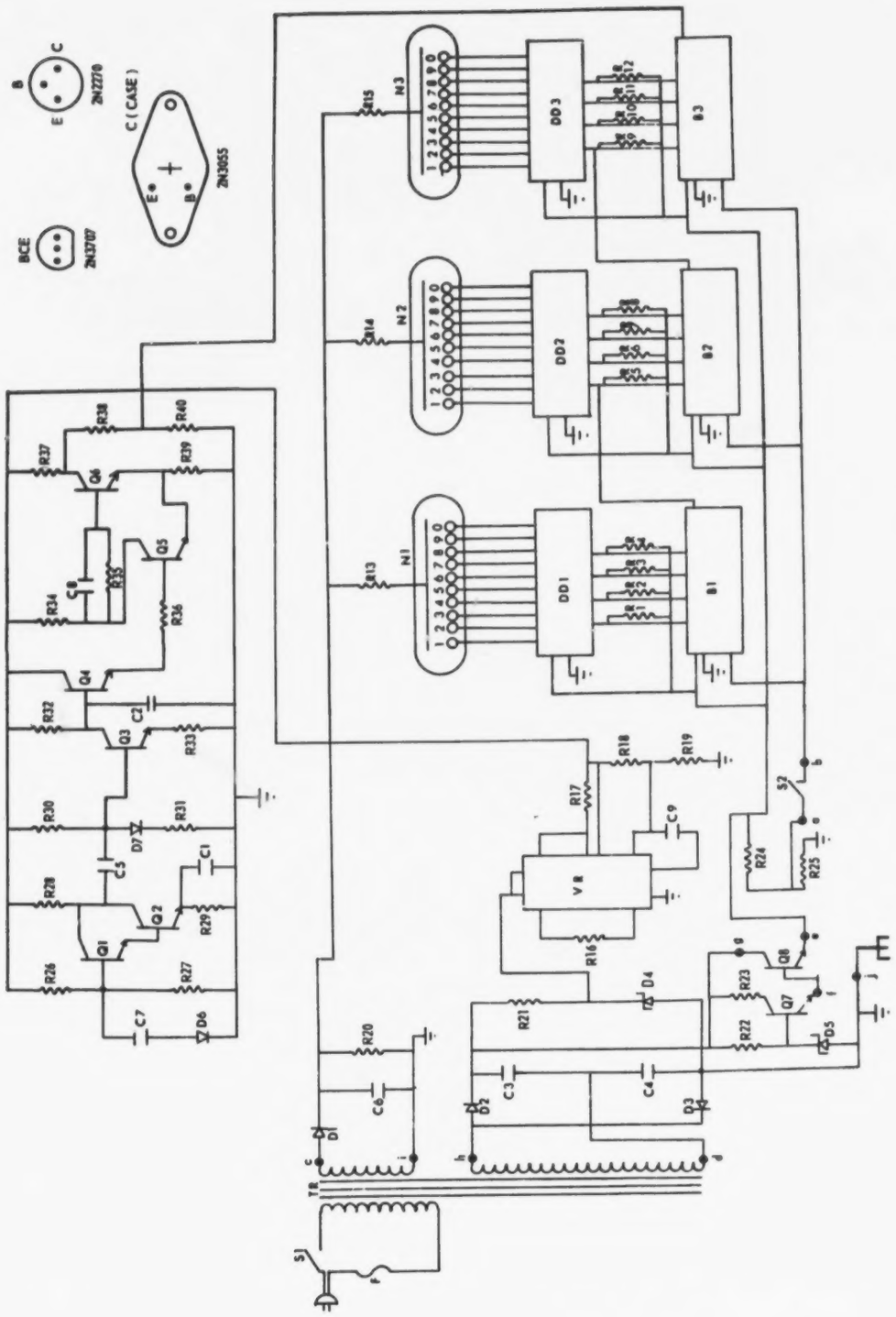


Figure 3. Schematic diagram of electronic x-ray pulse counter.

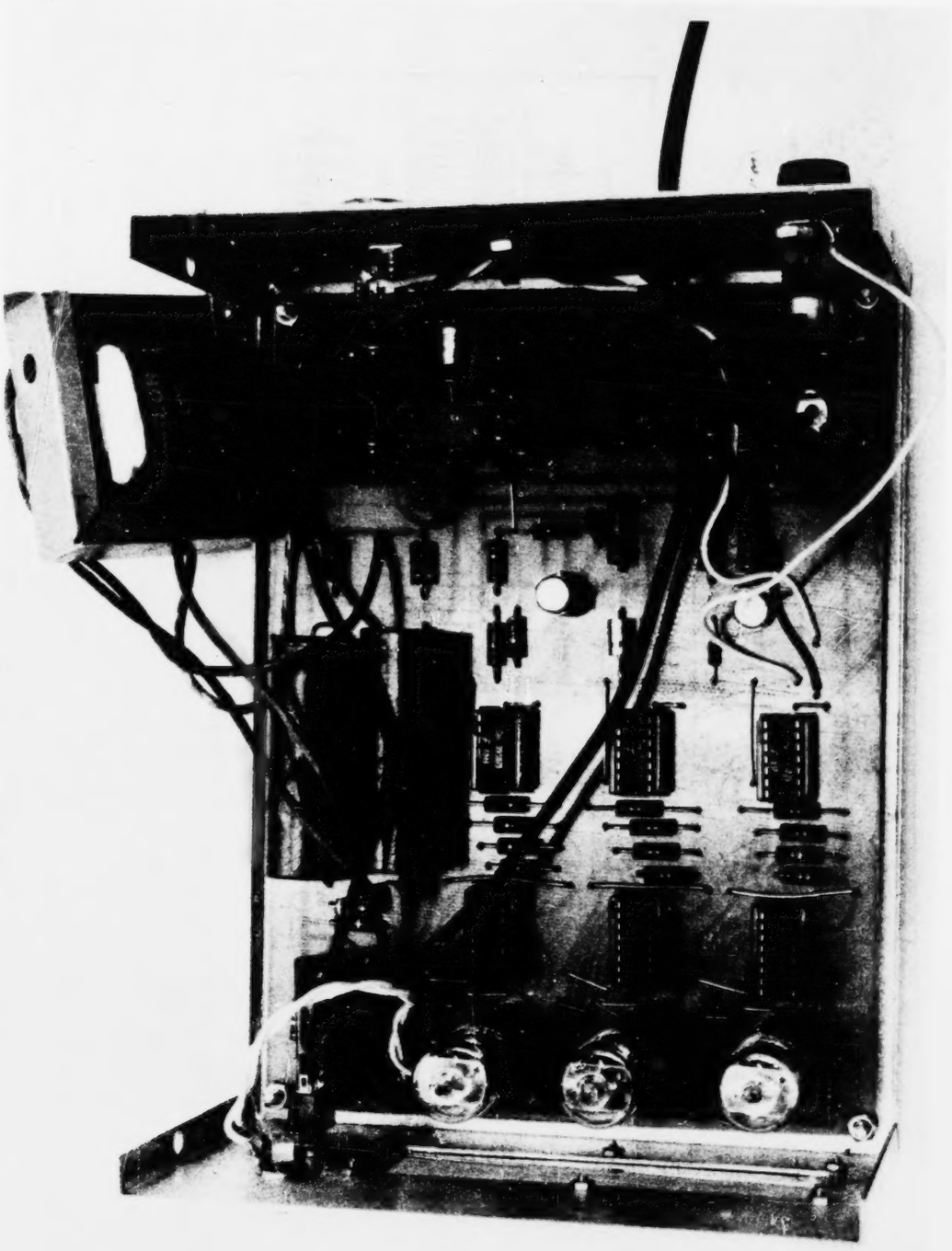


Figure 4. Interior view of electronic x-ray pulse counter.

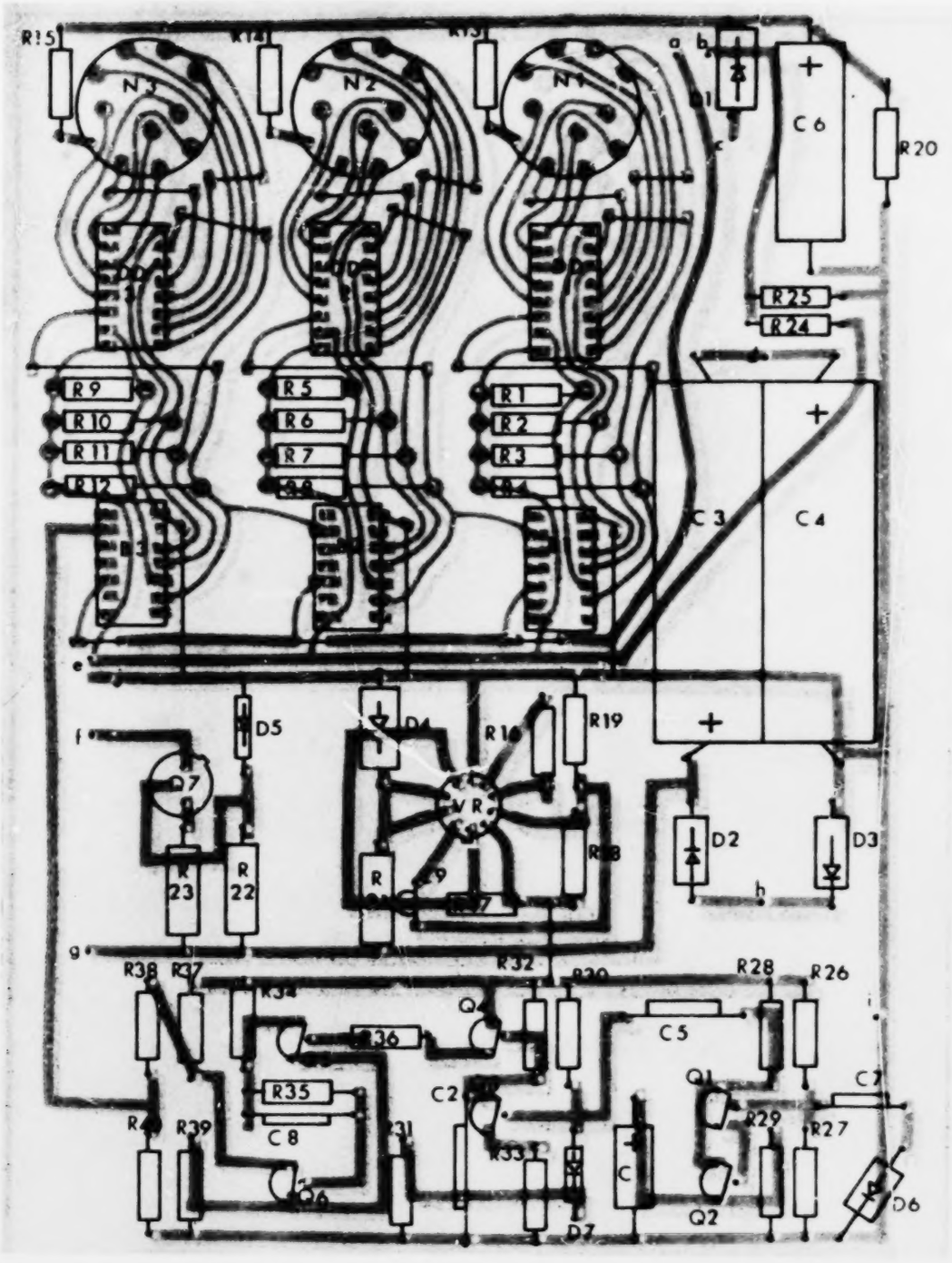


Figure 5. Printed circuit board top view with component outlines.

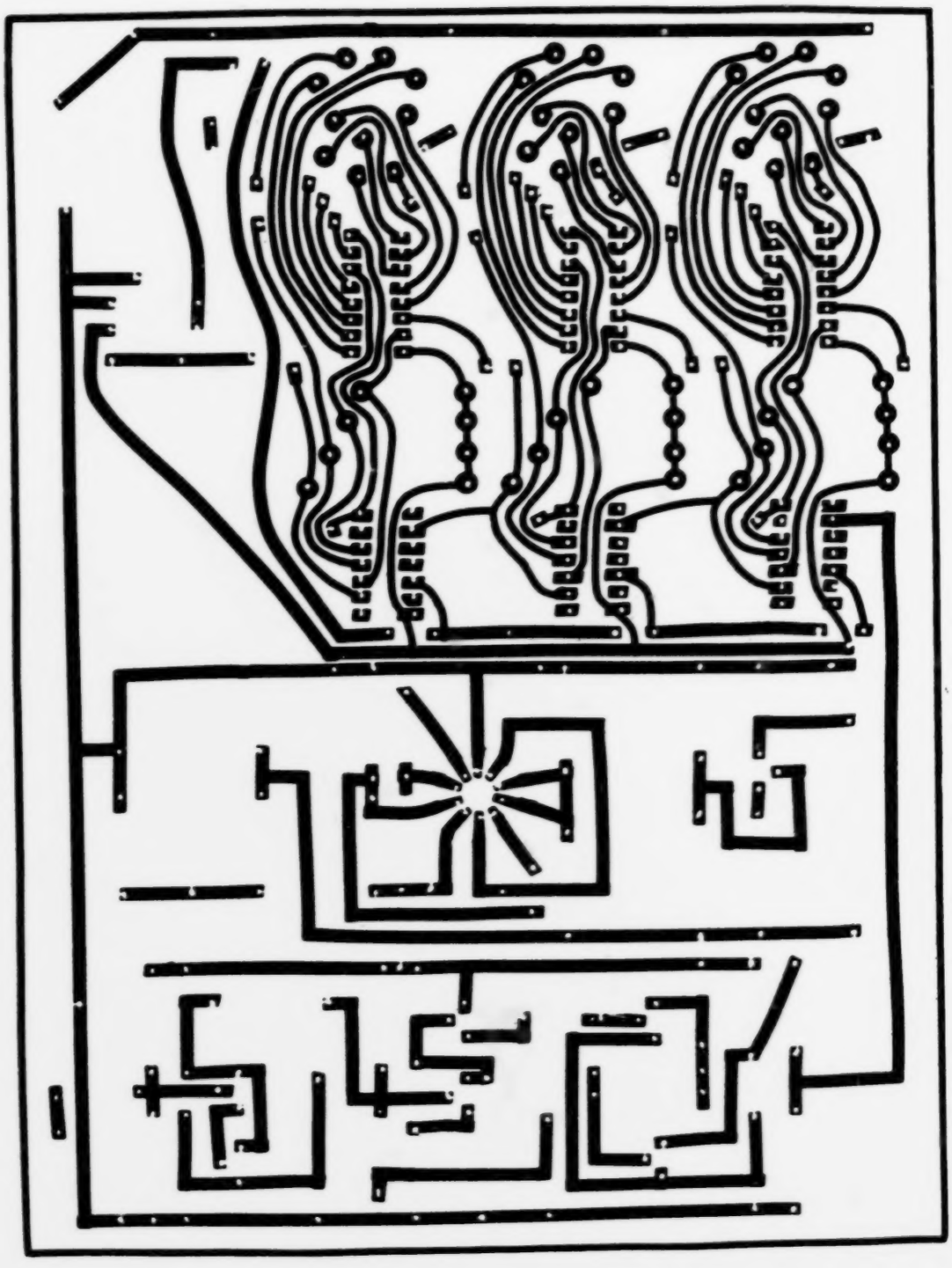


Figure 6. Printed circuit board pattern - bottom view.

APPENDIX A

COMPONENT LIST

BLANK PAGE

COMPONENT LIST

RESISTORS

R1-R15:20 K, 5%
R16:820 ohms
R17:10 ohms
R18:1 K, 5%
R19:7.5 K, 5%
R20:100 K
R21:180 ohms, 1 W
R22, R23:680 ohms, 1 W
R24:910 ohms, 5%
R25:1.8 K
R26:5.1 M, 5%
R27:2 M, 5%
R28:330 K
R29:100 K
R30:2 M, 5%
R31:330 K
R32:180 K
R33:10 K
R34:4.7 K
R35: R36: 20 K, 5%
R37:3.9 K
R38:4.7 K
R39:180 ohms
R40:1.8 K

All resistors 1/2 watt, 10% unless otherwise specified.

CAPACITORS

C_1:10 mfd., 6 V d.c.
C_2:0.005 mfd., 1 kV
C_3, C_4:2000 mfd., 15 V d.c.
C_5, C_7:0.01 mfd., 50 V d.c.
C_6:2 mfd., 450 V d.c.
C_8:0.02 mfd., 50 V d.c.
C_9:10 pfd., 50 V d.c.

TRANSISTORS

Q_1-Q_6:2N3707
Q_7:2N2270
Q_8:2N3055

DIODES

D_1-D_3,D_6:International Rectifier 5A4
D_4:IN3023
D_5:IN751 A
D_7:IN34 A

Preceding page blank

INTEGRATED CIRCUITS*

VR Fairchild Type UA723C (part #U5R7723393)
Voltage Regulator

B_1 - B_3 Fairchild Type CuL 9958 (part #U6A995879X)
BCD Counter

DD_1 - DD_3 Fairchild Type CuL 9960 (part #U6B996079X)
Decoder/Driver

*Technical information on the above ICs is available in the Fairchild Semi-Conductor Data Catalogue 1969 (4)

N_1 - N_3: National Type NL840 Readout Tube
TR: Stancor Type PS-8416 Power Transformer
S_1: Miniature S.P.D.T. - Toggle Switch
S_2: Miniature S.P.S.T. - Momentary Contact Switch
F : Fuse Post Type HKP with 3 AG 1/2 amp fuse

MISCELLANEOUS

16 Pin Dual In-Line IC Socket: Augat #316-AG1A (3 required)
14 Pin Dual In-Line IC Socket: Augat #314-AG1A (3 required)
10 Pin Concentric IC Socket : Cinch-Jones #10-ICS
Readout Tube Socket: National #RTS-14 (3 required)
Power Transistor Mounting Kit: Motorola #MK-15
Ten-foot line cord
7" x 10" Kepro photosensitive printed circuit board and processing solutions
Chassis clamp grommet for power cord
Aluminum minibox: 8" x 6" x 3-1/2"
Rubber chassis bumpers
Red plastic membrane (for readout window)
Metal screen wire (for detector window)
Machine screws
1/32" sheet aluminum for window frame